Combined effects of temperature, pH and water activity on predictive ability of microbial kinetic inactivation model

Maria M. Gil[a,b]; Fátima A. Miller[b]; Teresa R. S. Brandão[b]; Cristina L. M. Silva[b]*

[a]MARE – Marine and Environmental Sciences Centre, ESTM, Instituto Politécnico de Leiria, Campus , 2520-641 Peniche (Portugal)
*maria.m.gil@ipleiria.pt
[b]CBQF – Centro de Biotecnologia e Química Fina – Laboratório Associado, Escola Superior de Biotecnologia, Universidade Católica Portuguesa/Porto, 4202-401 Porto, Portugal

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INTRODUCTION

It is well known that temperature is the key factor controlling the microbial survival/inactivation. However, the interactive effects of further stressing environmental conditions may influence microbial inactivation behaviour. Water activity and pH are examples of environmental factors that greatly affect bacterial thermal resistance (as water activity increases, thermal resistance decreases; as pH decreases, thermal resistance decreases).

A number of mathematical models have been proposed for describing the effects of those factors on microbial kinetics. However, the effect of possible interactions is not commonly assessed. Besides this, one should be aware about the predictive capacity of the primary inactivation model in describing microbial behaviour, when those effects are included.

The objective of this work was to include, in the inactivation model, temperature, pH and water activity effects using a black box polynomial model, aiming at accurate prediction.

MODELS

A Gompertz-inspired model (Gil *et al*. 2011) was used :

$$y_{inact}(t) = \log\left(\frac{N}{N_0}\right) = \log\left(\frac{N_{res}}{N_0}\right)\exp\left(-\exp\left(-\frac{k_{max}\, e}{\log\left(\frac{N_{res}}{N_0}\right)}(L-t)+1\right)\right)$$

model parameters

Temperature, pH and water activity dependence of shoulder, maximum inactivation rate and tail was included in the previous equation and assumed to be polynomials: (the tail ($\log(N_{res}/N_0)$) was assumed to be independent of temperature, but dependent on pH and water activity.):

$$\log\left(\frac{N_{res}}{N_0}\right) = \sum_{i=0}^{n}\sum_{j=0}^{n} G_{Tail_{ij}}\, a_w^{k}\, pH^{j}$$

$$k_{max} = \exp\left(\sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=0}^{n} G_{k_{max\,ijk}}\, a_w^{k}\, pH^{j}\, T^{i}\right)$$

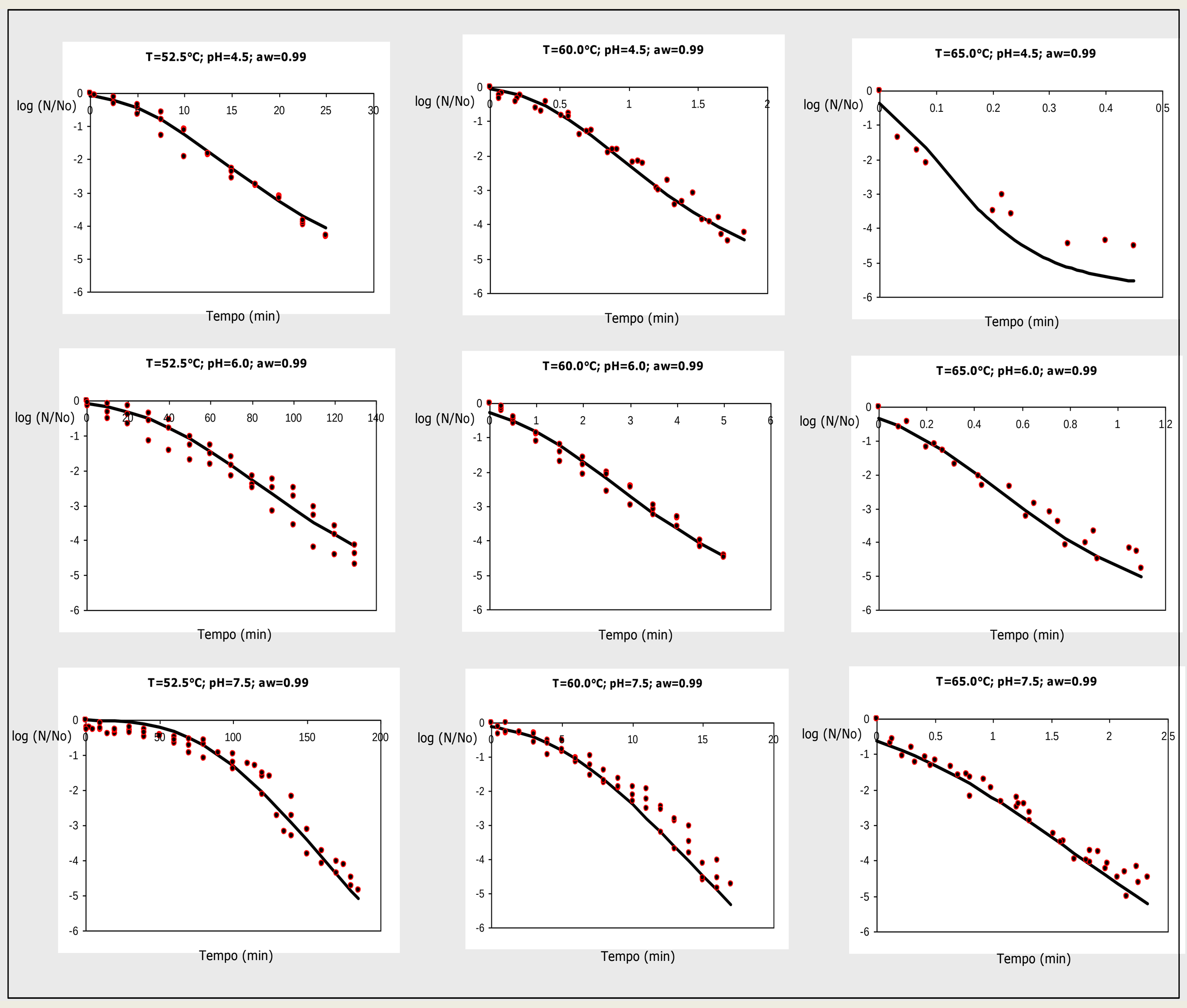
$$L = \exp\left(\sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=0}^{n} G_{L_{ijk}}\, a_w^{k}\, pH^{j}\, T^{i}\right)$$

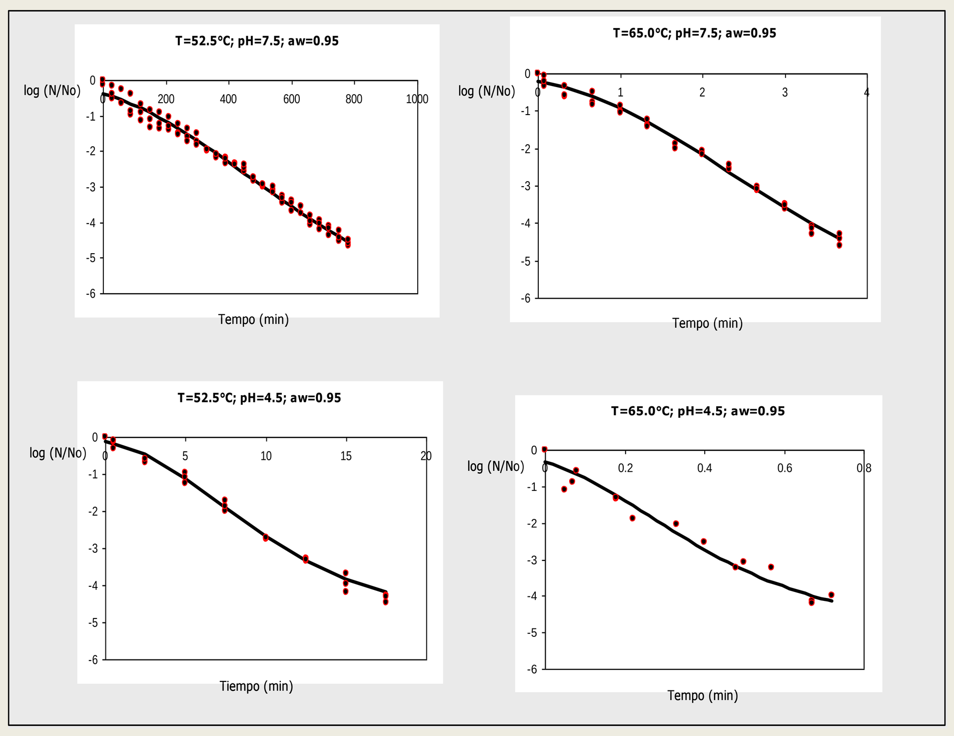
METHODOLOGY

- ◊ Experimental data of *Listeria innocua* obtained within the temperature range of 52.5 and 65.0 °C, pH of 4.5, 6.0 and 7.5, and water activity of 0.95 and 0.99 were used for model assessment (Miller *et al.* 2009).
- ◊ Inactivation experimental data of *Listeria innocua* obtained at different conditions of temperature, pH and water activity were fitted separately with the Gompertz-inspired model.
- ◊ The model parameters (k_{max}, L and $\log(N_{res}/N_0)$) were estimated at each one of the combined factors.
- ◊ Secondary models, that express the relations of kinetic parameters on environmental conditions, were purely empirical.
- ◊ Model parameters were estimated by non-linear regression analysis, using a flexible black box modelling approach.
- ◊ Model fitting procedures were performed using STATISTICA 6.0 (StatSoft, Inc. 2001, Tulsa, OK, USA) software, by least squares non-linear regression analysis.
- ◊ The adequacy of the models was tested by the coefficient of determination, and residuals analyses (randomness and normality).

RESULTS

- ◊ In the range of environmental factors studied, the model predicts successfully the inactivation kinetics (accurate predictions were observed).
- ◊ Besides the model developed is confined to *L. innocua* kinetics in the media studied, however this is certainly a contribution to design more efficient thermal inactivation processes with controlled influence of the stressing environmental factors.
- ◊ However, and for an insightful control of the water activity influence, further levels of this factor should be studied.
- ◊ Models that describe the effect of temperature, pH and water activity on sigmoidal behaviour (assessed by the shoulder period, maximum inactivation rate and tail) were successfully developed on the basis of polynomial functions.





When these mathematical relationships were included in the primary kinetic model, accurate predictions of the inactivation data were attained, thus validating the predictive ability of the model expressed in terms of the stressing environmental factors studied.

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